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(54) IMPROVEMENTS IN OR RELATING TO VAPOUR COATING OF MATERIALS IN A VACUUM

(71) We, VEB HOCHVAKUUM DRESDEN, of 26, Grunaer Weg, 8020 Dresden, Germany, a Corporation organised under the laws of Eastern Germany, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a method for the vapour coating of large surfaced materials in a vacuum, for example webs or sheets of paper, synthetic plastic materials, glass or metallic materials.

The vapour coating of materials is effected by vaporising a coating material by heating it with an electron beam or by heating it by thermal radiation or thermal conduction. The vaporiser element or vaporising crucible is in the latter case heated by current conduction. In production installations, it is frequently necessary to maintain stable vaporisation conditions over a long period of time. It is therefore necessary to provide a disturbance-free supply of material to be vaporised, and for the vaporiser to be able to withstand long periods of continuous running.

When using electron beams for heating the material to be vaporised, water-cooled copper crucibles are used. In most cases, however, special materials are used for the vaporising surface of the vaporiser, such as for example oxides, borides and metal ceramic compounds, and in these an alteration of the composition is effected at the vaporisation surface.

For the supply of the material to be vaporised, various possibilities exist. When using a water-cooled crucible, the material to be vaporised can for example be supplied in the form of rods upwardly through an open bottom of the crucible. It is quite common to supply the material to be vaporised in the form of wire, independently of the way in which the vaporiser is heated. A further possibility is to supply the material for vaporisation in the form of granules fed by means of a vibrating conveyor.

In most installations, the requirement exists of providing vapour coated layers which are of high homogeneity. In order to be able to coat wide moving surfaces, frequently a row of identical vaporisation arrangements are arranged at equal spacings from each other so as to extend in a direction perpendicular to the movement direction of the material to be coated. In this case, for each vaporiser, a separate supply of material to be vaporised is necessary. The feed of the material to be vaporised, for example wire, is effected from a common driving arrangement, at the same speed for each feeding device, for the sake of simplicity. The wire is fed to the centre of the heated vaporiser body and if the vaporiser is heated to a temperature which is higher than the melting temperature of the wire, and if the wire is not fed at too great a speed, then with suitable shaping of the vaporiser body a pool of molten material for vaporisation forms. For a constant feed speed of the material to be vaporised, if the temperature of the vaporiser body increases, the pool of molten material becomes smaller. With sufficiently high temperature practically an immediate vaporisation takes place of the maount of wire supplied at any instant. This kind of vaporisation is called flash vaporisation.

Some of the known vaporising arrangements have the disadvantage that the vaporiser bodies can withstand only short periods of continuous use. Moreover, the arrangement of a plurality of individual vaporising arrangements is disadvantageous when coating wide bands, since the degree of uniformity of the thickness of the coating, perpendicularly to the movement direction of the band, does not satisfy usual require-

[*Price 5s. 0d. (25p)*]

ments. Furthermore, the rate at which a wide band can be coated is too low for many purposes. With a point-shaped vaporiser and a flat surface guided over the vaporiser for coating, the coating thickness on this surface is proportional to $\cos^4\varnothing$, where $\varnothing$ is the angle between the normal to the surface and the connecting line between the point of vapour incidence and the vapour source. Even when a line-shaped vaporising body with a constant vapour density in the direction of this line is used, the length of the vaporiser body being approximately equal to the width of the surface to be coated, then on this surface a varying coating thickness is produced over the width of the surface, the coating thickness decreasing towards the margins. The same disadvantageous effect occurs if a row of point-shaped vaporisers with equal spacing and equal yields of vapour are arranged below the surface to be coated, in a row extending perpendicularly to the movement direction of the surface. A further disadvantage exists in the case of vaporiser bodies which are heated by means of current conduction, in that the central part is destroyed or damaged after a relatively short time due to the continuous incidence of the material to be vaporised thereon, this incidence being always at the same region.

It is an object of the invention to provide a method for the vapour coating of large surfaced materials, which can be performed at a high coating rate and which enables a uniform coating thickness to be obtained over the width of the material to be coated.

The invention consists in a method for the vapour coating of large surfaced materials in a vacuum during movement of the said material along a movement path, comprising the steps of moving the said material along the said movement path, feeding a wire of the substance to be vaporised onto a vaporiser arrangement heated by current conduction, inductively or by electron bombardment, vaporising the wire thereby and causing the vapour to be deposited on the material to be coated, the feeding of the wire being effected in such a manner that the region at which the wire engages a vaporising surface of the vaporiser arrangement moves over the said surface in accordance with a predetermined programme.

When the wire is fed with a constant forward speed, it is advantageous if the said engagement region is moved over the said surface at a constant or varying speed perpendicularly to the movement direction of the material to be coated, or in a programme involving both perpendicular movements and movements parallel to the said movement direction. Alternatively, the wire may be moved so that the said engagement region is moved over the said surface perpendicularly in the movement direction of the material to be coated, or in accordance with a programme combining perpendicular movement and movement parallel to the said movement direction, the forward feed of the wire being effected at a varying speed. In this way, it is possible to adapt the amount of wire vaporised, to the coating thickness desired at particular regions of the material to be coated.

The invention also consists in an apparatus for use in performing the abovedefined methods, comprising means defining a feed path for the material to be vapour coated and means for moving the material along the said feed path, at least one vaporiser having a generally rectangular vaporising surface arranged for being heated by current conduction, inductively or by electron bombardment, the vaporiser being so disposed relative to the feed path of the material to be coated, that the longitudinal dimension of the vaporising surface is perpendicular to the movement direction of the material to be coated and, when a single vaporiser is used, is at least equal in length to the width of the material to be coated, a wire feeding device having a pair of driven rollers arranged to draw wire from a supply roll and feed it to the vaporiser, means being provided for controlling the feeding of the wire in such a manner that the region at which the wire engages the vaporising surface moves over the said surface in accordance with a predetermined programme.

When the vaporiser is arranged for being heated by current conduction, its cross section may be non-uniform over its length, so as to be adapted to the programme according to which the wire for vaporisation is fed.

The wire feeding device may comprise a plurality of supply rolls of wire, and pairs of driven feed rollers, whereby to feed wire to spaced-apart engagement regions on the vaporising surface, or to vaporising surfaces of individual vaporisers. A plurality of jointly operable vaporisers may be provided. which are disposed in a row extending perpendicularly to the movement direction of the material to be coated, the vaporisers having a smaller spacing from each other at the end regions of the row than at the centre of the row, a plurality of wire feeding arrangements arranged in a row being provided for feeding wire to the individual vaporisers. The diameter of the wire or of the feed rollers of the individual feeding devices may be larger for the feeding devices at the end regions of the row than at the centre of the row, and all of the vaporisers may be arranged for being heated to the same temperature. The differential spacing of the various vaporisers in the row enables the fall-off in thickness of the coat-

ing towards the margins of the material to be coated, to be compensated, and by suitable choice of the spacings, wide bands can be vapour coated in a uniform manner, with fewer vaporising arrangements than would be the case if they were uniformly spaced.

The vaporisers may be arranged in a plurality of rows, the rows extending perpendicularly to the movement direction of the material to be coated, and the rows being disposed successively in the said movement direction.

All of the wire feeding devices may be arranged on a common carrier, for example so as to be jointly movable. The individual wire feeding devices may be provided with wire of different materials, so that the composition of the vapour coating may vary over the width of the material to be coated.

In order to make the invention clearly understood, reference will now be made to the accompanying drawings which are given by way of example and in which:—

Fig. 1 is a diagrammatic sectional view of a vapour-coating apparatus, according to the invention;

Fig. 2 illustrates a vaporiser body and shows a possible programme according to which the feed of wire to the vaporiser body can be controlled;

Fig. 3 is a plan view of a modified vaporiser apparatus having a single vaporiser body and a wire feeding device arranged for feeding a plurality of wires thereto;

Fig. 4 is a plan view of a vaporiser apparatus suitable for very wide bands to be vapour-coated; and

Fig. 5 is a plan view of a vaporiser apparatus suitable for very wide bands and for providing thick coating layers thereon.

The principle of the vapour coating apparatus of the invention can be seen from Fig. 1. In a wire feeding device 1, a supply roll 2 for the wire 3 is provided, the wire 3 constituting the material to be vaporised. Two driven rollers 4 draw the wire 3 from the supply roll 2 and feed it through a guide tube 5 onto the vaporising surface 6 of a vaporiser body 7 which is heated by direct current conduction, the vaporiser body causing the wire 3 to be flash-vaporised on the surface 6. Above the vaporiser body 7, the material 8 to be coated is guided in the direction y, by feed means (not shown). The wire feeding device 1 is mounted on a carrier 9. In order to move the point of incidence of the wire 3 on the vaporising surface 6, the wire feeding device 1 is moved to and fro in accordance with a pre-determined programme, perpendicularly to the movement direction y of the material to be coated, and possibly also parallel to this movement direction during part of the programme. As well as this position-dependent programme, additionally the speed v of this movement can be varied, as can be seen from Fig. 2. In Fig. 2, the example is illustrated in which the speed v in the movement direction x, that is to say in the longitudinal direction of the vaporiser surface 6, this being transverse to the movement direction y of the material 8, is reduced towards the margins of the material 8 so that more wire 3 is vaporised at the parts of the vaporising surface 6 corresponding to the margins of the material 8, whereby to prevent a fall-off in thickness of the coated layer at these margins. The wire 10, in its movement on the vaporising surface 6, describes a closed loop 10. The vaporiser body 7 is arranged with its longitudinal direction perpendicular to the movement direction y of the material 8 to be coated. The entire arrangement is disposed in a vacuum chamber, which is not illustrated. The vaporiser body 7 is mounted between water-cooled clamping arrangements 11. A diaphragm 12 is provided which has an opening therein allowing the vapour to reach the material 8.

With increasing width of the material 8 to be coated, it is necessary to increase the length of the vaporiser body 7. The movement of the wire 3 over the entire length of the vaporising surface 6 has to be adapted to the throughput speed of the material 8 to be coated. With large speeds, difficulties occur in the obtaining of a homogeneous layer thickness perpendicularly to the movement direction y of the material 8. These difficulties can be overcome if as shown in Fig. 3, a plurality of wires 3 are fed to a vaporiser body 7. Thus, in a single wire feeding device 1, three supply rolls 2 for wires 3 are provided and three pairs of rollers 4 are provided for drawing the wires from the supply rolls 2 and for supplying the same to the vaporising surface 6. Thus, it is possible to operate with a single vaporiser body 7 the length of which is at least equal to the width of the material 8 to be coated. The vaporiser body 7 is thermally loaded uniformly over its length and thus has a longer lifetime. By suitably increasing the rate of feed of the material to be vaporised at portions of the vaporiser body corresponding to the margins of the material 8 to be coated, a uniform coating can be obtained over the entire width of the material 8. The wire feeding device 1 is moved as a unit in accordance with the desired control programme.

The apparatus shown in Fig. 4 is particularly suitable for the coating of bands of great width. A plurality of wire feeding devices 1 are provided, which are arranged in a row extending perpendicularly to the movement direction y of the material 8 to be coated, this material not being shown in Fig. 4 but being shown in Fig. 1. The individual wire feeding devices 1 are arranged

on a common carrier 9 and the provision of a plurality of vaporiser bodies 7 enables a greater width to be covered than would be the case with a single vaporiser body. In order that constant layer thicknesses can be achieved over the entire width of the material 8 to be coated, the spacing a_1 of the outermost wire feeding devices must be less than the spacing a_2 of the central wire feeding devices. The relationship between a_1 and a_2 is determined by the distance of the vaporiser bodies 7 from the surface to be coated, and the lengths of the vaporising surfaces 6. There is an optimum value for the ratio of the spacings a_1 and a_2. The feeding speed of all of the feed devices for the wires are the same, so that a single drive can be used for all of the feed rollers 4. The carrier 9, and thus all of the wire feeding devices 1 is movable in accordance with a time programme or in accordance with a position programme, in the directions y and x. Additional compensation of the fall-off in layer thickness at the margin of the material 8 to be coated may be effected if the vaporising bodies 7 which are allocated to the marginal regions of the material 8 are given such a cross section that they are more strongly heated, the wire 3 being fed to these particular vaporising bodies 7 at a faster speed. This can be done while nevertheless using a common drive for all of the various rollers 4, by making those rollers 4 which are used for feeding wire to the more intensely heated vaporising devices, so as to have a larger diameter than the rollers of the other feeding devices, so that wire is fed at a faster rate. Alternatively, for these particular wire feeding devices, wire of a thicker diameter than the wire of the other devices can be used, so that although each wire feeding device feeds an identical length of wire, these particular feeding devices feed a larger volume of wire in any given time.

Fig. 5 shows an apparatus suitable for coating very wide bands at a high coating rate. Since the rate of vaporisation from any of the vaporising bodies 7 is limited by the maximum operating temperature, an increase in the rate of vapour coating can be obtained if a number of rows of vaporisers are disposed one after the other. Thus, the apparatus shown in Fig. 5 has two rows of vaporising bodies 7 the rows being arranged parallel to each other one after the other in the direction of feed of the material to be coated, that is to say the direction y. The apparatus of Fig. 5 is similar to that shown in Fig. 4 but two groups of wire feed devices and vaporisers are used, arranged one after the other in the direction of movement of the material to be coated. As in the embodiment of Fig. 4, the wire feeding devices 1 are arranged on a common carrier 9 so that they can be displaced as a unit, according to the predetermined programme, in the direction x and in the direction y. The use of two rows of vaporisers has also the advantage that the individual vaporisers do not have to be aperated close to their maximum operating temperature, so that their useful life is increased. Moreover, there is the possibility of using a different material for vaporisation in each row, so that the vapour coating can comprise several different materials.

WHAT WE CLAIM IS:

1. A method for the vapour coating of large surfaced materials in a vacuum during movement of the said material along a movement path, comprising the steps of moving the said material along the said movement path, feeding a wire of the substance to be vaporised onto a vaporiser arrangement heated by current conduction, inductively or by electron bombardment, vaporising the wire thereby and causing the vapour to be deposited on the material to be coated, the feeding of the wire being effected in such a manner than the region at which the wire engages a vaporising surface of the vaporiser arrangement moves over the said surface in accordance with a predetermined programme.

2. A method as claimed in claim 1, wherein the wire is so moved that, the said engagement region is moved over the said surface at a constant or varying speed perpendicularly to the movement direction of the material to be coated or both perpendicularly and parallel to the said movement direction.

3. A method as claimed in claim 2, wherein the forward feed of the wire is effected at a constant speed or at a varying speed.

4. Apparatus for use in performing the method of claim 1, 2 or 3, comprising means defining a feed path for the material to be vapour coated and means for moving the material along the said feed path, at least one vaporiser having a generally rectangular vaporising surface arranged for being heated by current conduction, inductively or by electron bombardment, the vaporiser being so disposed relative to the feed path of the material to be coated, that the longitudinal dimension of the vaporising surface is perpendicular to the movement direction of the material to be coated and, when a single vaporiser is used, is at least equal in length to the width of the material to be coated, a wire feeding device having a pair of driven rollers arranged to draw wire from a supply roll and feed it to the vaporiser, means being provided for controlling the feeding of the wire in such a manner that the region at which the wire engages the vaporising surface moves over the said surface in accordance with a predetermined

programme.

5. Apparatus as claimed in claim 4, wherein the vaporiser is heated by current conduction and its cross section varies over its length so as to be adapted to the programme according to which the wire for vaporisation is fed.

6. Apparatus as claimed in claim 4 or 5, wherein the wire feeding device comprises a plurality of supply rolls of wire, and pairs of driven feed rollers, whereby to feed wire to spaced-apart engagement regions on the vaporising surface, or to vaporising surfaces of individual vaporisers.

7. Apparatus as claimed in claim 4 or 5, wherein a plurality of jointly operable vaporisers are provided which are disposed in a row extending perpendicular to the movement direction of the material to be coated, the vaporisers having a smaller spacing from each other at the end regions of the row than at the centre of the row, a plurality of wire feeding devices arranged in a row being provided for feeding wire to the individual vaporisers.

8. Apparatus as claimed in claim 7, wherein the diameter of the wire or of the feed rollers of the individual feeding devices is larger for the feeding devices at the end regions of the row than at the centre of the row, and all of the vaporisers are arranged for being heated to the same temperature.

9. Apparatus as claimed in claim 6, 7 or 8, wherein the vaporisers are arranged in a plurality of rows, the rows extending perpendicularly to the movement direction of the material to be coated, and being disposed successively in the said movement direction.

10. Apparatus as claimed in claim 7, 8 or 9, wherein all of the wire feeding devices are arranged on a common carrier.

11. Apparatus as claimed in any one of claims 7 to 10, wherein the individual feeding devices are provided with wire of different materials.

12. A method as claimed in claim 1, for the vapour coating of large surfaced materials in a vacuum, substantially as hereinbefore described.

13. Apparatus for use in performing the method of claim 12, constructed and arranged substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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1,203,069 COMPLETE SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 1

FIG.1

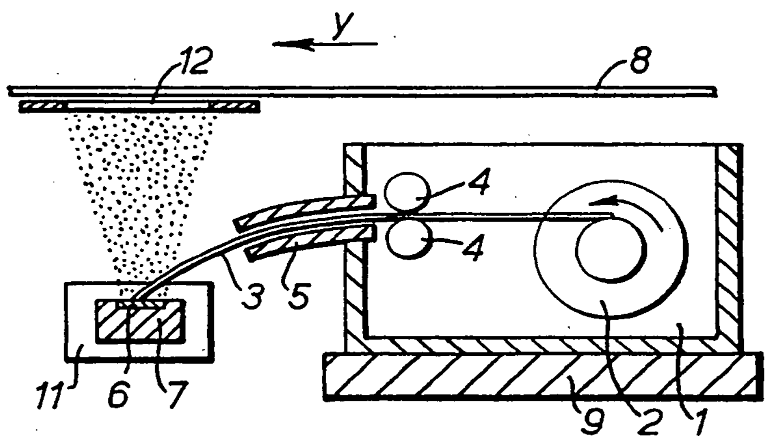

FIG. 2

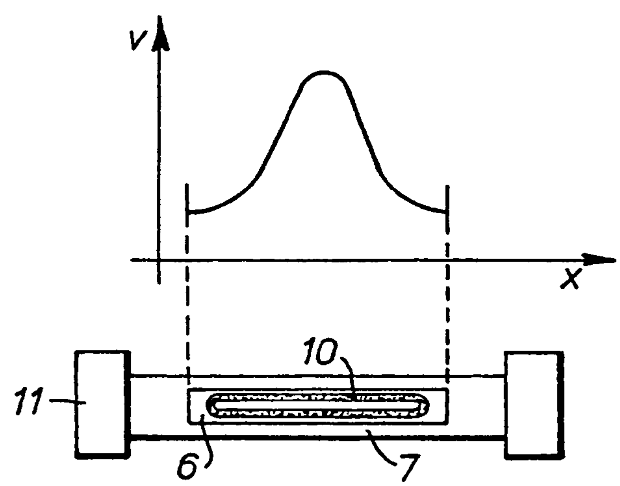

FIG. 3

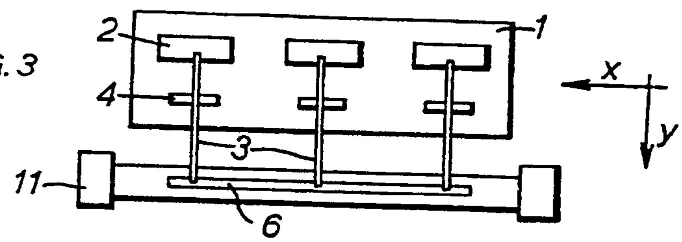

FIG. 4

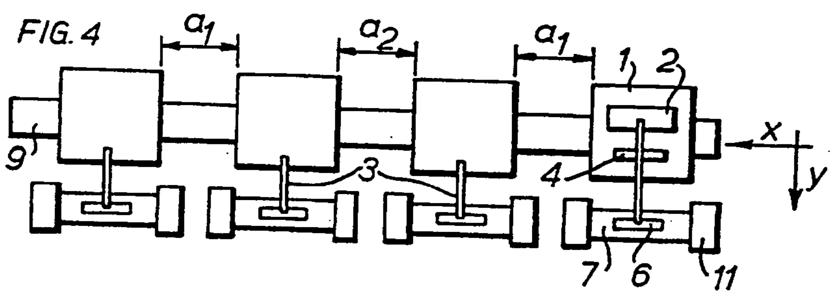

FIG. 5